International Biodeterioration & Biodegradation 106 (2016) 117–126

Contents lists available at ScienceDirect

International Biodeterioration & Biodegradation

journal homepage: www.elsevier.com/locate/ibiod

Bioremediation of creosote contaminated soil in both laboratory and field scale: Investigating the ability of methyl-β-cyclodextrin to enhance biostimulation

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ARTICLE INFO

Article history:
Received 22 June 2015
Received in revised form
19 October 2015
Accepted 19 October 2015
Available online 30 October 2015

Keywords:
Soil bioremediation
Cyclodextrin
Surfactant
Biodegradation
Biostimulation
Polycyclic aromatic hydrocarbon

ABSTRACT

We investigated the bioremediation of 16 polycyclic aromatic hydrocarbons (PAH) in historically creosote contaminated soil using both laboratory and field scale experiments. We found that nutrient amendments and circulation of methyl-β-cyclodextrin (CD) solution enhanced soil microbial degradation capacity. In the laboratory experiment, the degradation of lower molecular weight, 2–3 ringed PAHs was achieved already by circulating nutrient solution and the use of CD mainly increased the desorption and removal of larger, 4–5 aromatic ringed PAH compounds. The 1% CD concentration was most feasible for bioremediation as most of the extracted PAH compounds were degraded. In the 5% CD treatment, the PAH desorption from soil was too fast compared to the degradation capacity and 25% of the total PAH amount remained in the circulated solution. Similar lab-scale results have been generated earlier, but very little has been done in full field scale, and none in freezing conditions. Although freezing stopped circulation and degradation completely during the winter, PAH degradation returned during the warm period in the field test. Circulation effectiveness was lower than in the laboratory but the improved nutrient and moisture content seemed to be the main reason for decreasing soil PAH concentrations. It also appeared that PAH extraction yield in chemical analysis was increased by the CD treatment in field conditions and the results of CD-treated and non-treated soil may therefore not be directly comparable. Therefore, a positive effect of CD on PAH degradation velocity could not be statistically confirmed in the field test. Based on our results, we recommend initiating the bioremediation of PAH contaminated soil by enhancing the microbial degradation with nutrient amendments. The CD seems to be useful only at the later stage when it increases the solubilisation of strongly absorbed contaminants to some extent. More investigation is also needed of the CD effect on the PAH yield in the chemical analysis.

1. Introduction

Creosote has been used for decades in wood impregnation processes to preserve and waterproof wooden structures like railway sleepers, telephone poles and bridge and pier deckings. The annual creosote production has been up to 100,000 tons in both Europe and in the USA, the main use being in the wood preservation industry (Melber et al., 2004), where the spills in wood preserving plants or releases from treated wood products have contaminated the soil. The European Soil Data Centre estimated that wood and paper industry contributes to nearly 4% of soil contamination in Europe and that polycyclic aromatic hydrocarbons (PAHs) have a role in nearly 11% of all soil contamination (Panagos et al., 2013). In Finland, approximately 6% of all contaminated land sites are contaminated by creosote and most of these are in the premises of old sawmills (Suni et al., 2007).

Coal tar creosote is a dark, oily liquid formed by fractional distillation of crude coal tars in 200–400 °C. It consists of a complex mixture of several hundred chemicals, of which only 20% are present in amounts greater than 1%. The composition of creosote varies

Abbreviations: PAH, polycyclic aromatic hydrocarbon; CD, cyclodextrin.

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http://dx.doi.org/10.1016/j.ibiod.2015.10.013
0964-8305/